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## Design Considerations for Enclosed Turboprop Engine Test Cells

### RATIONALE

Propose to stabilize this document as there is no new information to be included in the document.

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## FOREWORD

Enclosed turboprop engine test cells are needed to provide a controlled environment during engine testing. Ever increasing sophisticated engine technology, performance requirements and safety and environmental concerns continually generate the need to improve test cell designs.

Propeller equipped turboprop engines operating in an enclosed engine test cell generate/encounter conditions directly attributable to the design characteristics of the test cell. Although in a very broad sense some of the conditions are common to all engine test cells, there are some that are unique to operations of propeller equipped engines in enclosed test cells. This report provides some of the most important factors that must be considered when designing an enclosed test cell for testing those engines. Desired engine performance, aero/thermodynamics, acoustic capability, mechanical integrity and safety requirements are described.

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## 1. SCOPE

This document is offered to provide state-of-the-art information about design factors that must be considered in the design of new or significantly modified engine test cells used to test propeller equipped turboprop engines in either QEC or bare engine configurations. The report does not address design considerations for test cells designed to test turboprop engines with dynamometer type load absorption devices because they are essentially tested as turboshaft engines. Design considerations for those test cells are presented in AIR4989, Reference 2.1.

### 1.1 Purpose

- a. Provide guidelines for factors that must be considered to design state-of-the-art enclosed engine test cells used to test propeller equipped turboprop engines.
- b. Provide empirical data/information about aerodynamic characteristics of propeller equipped engine testing in enclosed test cells.
- c. Provide empirical acoustic data/information from propeller equipped engine test operations in enclosed test cells.

## 2. REFERENCES

- 2.1 AIR4989 - Design Considerations for Enclosed Turboshaft Engine Test Cells.
- 2.2 NFPA 423 - Standard for Construction and Protection of Aircraft Engine Test Facilities.
- 2.3 Naval Air Warfare Center, Patuxent River Maryland, Propulsion Support Equipment Branch, TECHEVAL Multi-Capability Turboshaft/Prop Engine Test Facility Complex, A/F 37T-16(v)1, 2 and A/F 37T-19(v)2, 3, Report No. 48L-95-027 dated 19 October 1995.
- 2.4 AIR5026 - Test Cell Instrumentation.
- 2.5 ARP5305 - Structural Design and Construction Considerations for Enclosed Turbofan/Turbojet Engine Test Cells
- 2.6 EPA-453/R-94-068 - Joint Report to Congress on the Environmental Protection Agency-Department of Transportation Study of Nitrogen Oxide Emissions and Their Control From Uninstalled Aircraft Engines in Enclosed Test Cells, Final report dated October 1994.
- 2.7 Naval Air Test Center Facilities Operation and Evaluation Report, A/F 37T-19(v) 1 Turboprop Engine Test Facility, Futema, Japan, 13600 Ser. SY53J/100 dated 10 March 194.
- 2.8 Naval Air Warfare Center, Lakehurst, New Jersey, Design Data Report Acoustic Evaluation of NAS Brunswick, Maine, Report No. NAWCADLKE-DDR-487100-0004, dated 18 April 1997.

## 3. TECHNICAL BACKGROUND

Enclosed turboprop engine test cells in use today vary from modified reciprocating engine test cells, to simple open end shelters with adjoining control cab, to state-of-the-art facilities designed for current and future engine testing. These test cells are designed to either test turboprop engines connected to a dynamometer type load absorption device or engines with a propeller installed. Design considerations for test cells incorporating dynamometers are presented in AIR4989 and will not be addressed here except for comparison purposes if necessary.

Turboprop engines operating in enclosed test cells can encounter problems directly attributable to the cell design characteristics. These problems can include fluctuating engine speed, high prop (propellor) stress and temperature and shaft horsepower (SHP) indications which can cause unnecessary test rejection and costly engine rework or in worst cases engine overtemperature or stalls resulting in serious engine damage or catastrophic failure. Most of these problems are caused by insufficient or distorted airflow through the test cell inlet and front cell area or insufficient exhaust section flow area. These conditions have even more detrimental effect on propeller equipped engines than on engines tested with dynamometers because of their effect on the propeller speed and service life.

#### 4. TEST CELL SYSTEM DESIGN CONSIDERATIONS

General design concepts illustrating the major features of enclosed turboprop engine test cell designs are shown in Figures 1, 2, 3, and 4. The major structural sections of the test cells are an inlet, test chamber, and an exhaust section. Some designs include an orifice wall and/or augmentor tube and either an overhead or floor mounted engine test stand or portable cart. Each must be tailored for its specific function and also be compatible with the other sections to achieve proper aero/thermodynamic and acoustic performance of the engine test cell. Each section will be described in terms of its purpose and functional performance. Fire protection guidelines of NFPA 423, Reference 2.2, should be followed when designing new or modified test facilities.

The test chamber and exhaust sections of test cells used to test propeller equipped engines are subjected to severe buffeting from the propeller wake which causes damage to ancillary equipment and instrumentation cables and hoses. Some cases of structural damage reportedly have been encountered in both old and more recently built test cells. Particular attention should be given to this operating condition during test cell design efforts.

Noise pollution concerns are increasing the need for enclosed engine testing and improved test cell noise attenuation. The low frequency noise generated by propeller equipped engines is particularly noticeable and should be addressed in the test cell design considerationis.

##### 4.1 Inlet Section

The primary purpose of the inlet section is to provide a sufficient uniform flow of air to the engine and propeller in the test chamber. It is designed to reduce the effect of crosswinds and attenuate the noise generated by the propeller and engine.

Most inlet sections are designed to provide either straight through horizontal airflow or, through the use of turning vanes, vertical to horizontal airflow to the test chamber, propeller and engine. Horizontal inlet sections theoretically should provide more uniform airflow than vertical inlets and are less expensive to build. However, because they may be more affected by ground effects, crosswinds and require more on-going foreign object damage (FOD), hazard control and extra noise attenuation the cost savings would be reduced. Vertical inlet sections require the additional vertical structure, turning vanes and possibly an additional pressure drop screen, all of which add significantly to the cost of the test cell. Designers should thoroughly analyze the proposed site for a test cell considering prevailing winds, adjacent structures, proximity of personnel not involved in engine testing, potential for generating FOD hazards, i.e., vehicle and personnel traffic and certainly local noise tolerance/ordinances before deciding on the design configuration. A FOD screen should be incorporated into a prop cell due to the high massflow, with care taken to ensure that the bottom edge is sealed at the floor to prevent debris from migrating along the floor and past the screen.

Erosion resistant concrete should be used in "brick and mortar" design test cell inlets. Corrosion resistant metals should be used in prefabricated test cells. Acoustic treatment should be provided that doesn't lose its effectiveness when subjected to rain/sleet/snow. It should be designed to keep the acoustic material dry so that the material will not drop to the bottom of its containment space as a result of frequently being wet. There should be no protrusions, recesses or uneven surfaces in the inlet structure that would distort uniform airflow. Basic temperature and pressure sensors should be incorporated connected to control room monitors. The design should ensure that all mechanical connections are secured with captive nuts, bolts, pins, etc., to reduce FOD potential. An engine access/service door large enough to allow a propeller equipped engine to be moved into the test chamber may be located in the front of the test cell or to the side depending on the overall configuration of the cell. If it is desired to delay installing the propeller until after the engine is installed in the test cell propeller handling features should be included in the cell design. Easy access to all areas of the inlet should be included to allow periodic inspections. A drainage system may be required depending on the average amount of precipitation in the area and the inlet configuration. Sufficient uniform airflow to the engine and propeller in the test chamber is dependent on a well designed inlet. Every effort should be made to provide this feature which is key to accurate stable repeatable engine performance testing.

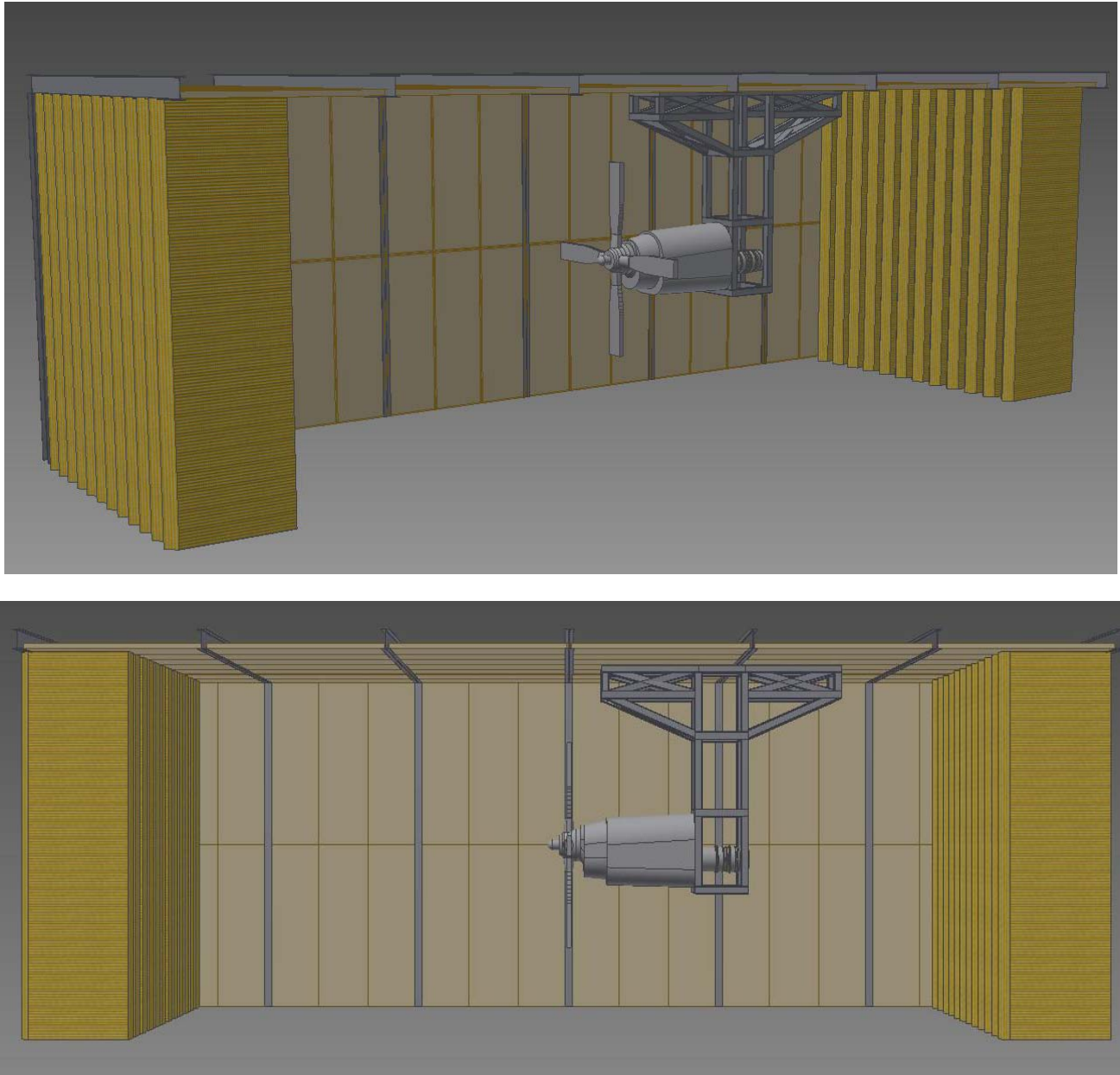


FIGURE 1 - TURBOPROP ENGINE TEST CELL WITH OVERHEAD TEST STAND,  
HORIZONTAL INLET AND EXHAUST SECTIONS WITHOUT INLET AND  
EXHAUST COURTYARDS OR ORIFICE WALL